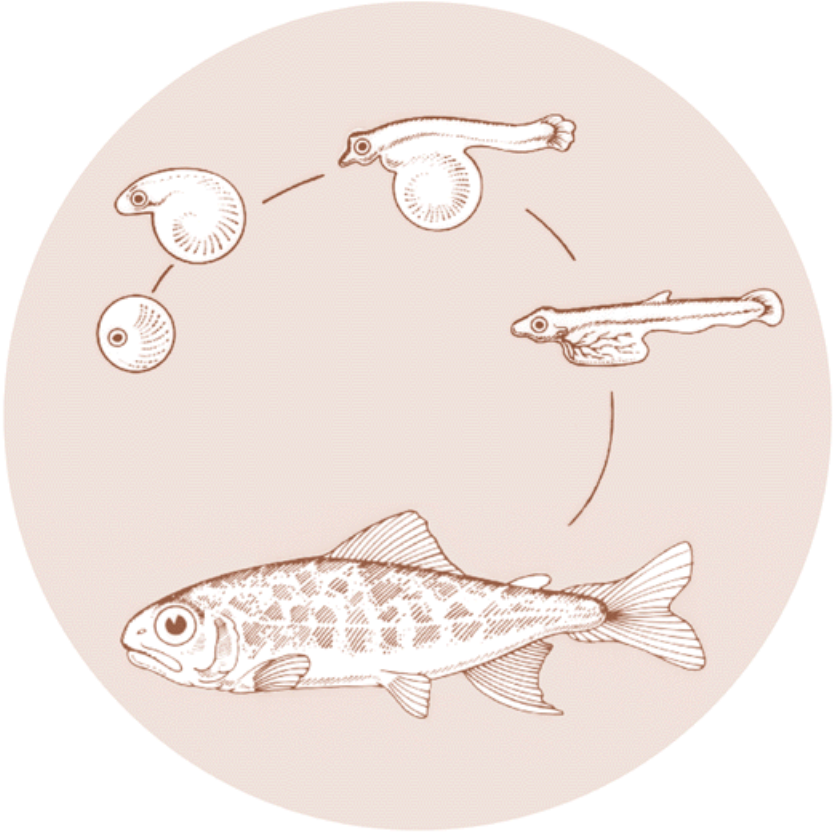
February 1990

PEN REARING AND IMPRINTING OF FALL CHINOOK SALMON

Annual Report 1989



DOE/BP-13084-5

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

Beeman, John W., U. S. Fish and Wildlife Service, Seattle National Fishery Research Center; Novotny, Jerry F. - Division of Federal Aid, U. S. Fish and Wildlife Service, Pen Rearing and Imprinting of Fall Chinook Salmon, Annual Report 1989 to Bonneville Power Administration, Portland, OR, Contract 83-AI-13084, 40 electronic pages (BPA Report DOE/BP-13084-5)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

PEN REARING AND IMPRINTING OF FALL CHINOOK SALMON

Annual Report 1989

Prepared by:

John W. Beeman

U. S. Fish and Wildlife Service
Seattle National Fishery Research Center

Jerry f. Novotny

Division of Federal Aid
Regional Office
U. S. Fish and Wildlife Service

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
PO Box 3621
Portland, Oregon 97208

Contract No. DE-AI79-83BP13084

February 1990

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

The goal of this project is to compare net-pen rearing methods to traditional hatchery methods of rearing upriver bright fall chinook salmon (Oncorhynchus tshawytscha). Fish were reared at several densities in net pens at three Columbia River backwater sites during 1984-1987, and in a barrier net at one site during 1984-1986; methods included both fed and unfed treatments. The purpose of this report is to summarize the results obtained from the unfed treatments and the current return of adults from all fed treatments and the barrier net.

Zooplankton were the primary food item of unfed fish. Fish reared in net pens utilized insects colonizing the nets as an additional food source, whereas those reared in the barrier net did not.

Growth and production of fish reared in the unfed treatments were low. Instantaneous growth rates of unfed fish were much lower than those of the fed treatments and hatchery controls except when zooplankton densities were high and chironomid larvae were important in the diet of unfed fish reared in pens. Only fish in the barrier net treatment resulted in consistent net gains in growth and production over the rearing periods.

Adult returns of fish from all fed and unfed treatments are lower than those of control fish reared at the hatchery. Returns appear to be inversely related to rearing density. Even though adult returns are lower than those of traditional hatchery methods, a cost-benefit analysis, as return data becomes more

complete, may prove these methods to be an economical means of expanding current hatchery production, particularly if "thinning" releases were used.

INTRODUCTION

The goal of this project is to compare off-station rearing strategies with traditional hatchery methods. Upriver bright fall chinook salmon (Oncorhynchus tshawytscha) were reared in net-pens at three backwater sites along the Columbia River and in a barrier net enclosure at one site (Novotny et al. 1984, 1985, 1986a, 1986b, 1987, 1988).

Rearing methods included feeding a full hatchery ration (3-4% body weight per day) to fish held at several densities in net pens and rearing fish without supplemental feeding in net pens at three densities and in one barrier net enclosure. These "unfed" treatments were tested to determine the densities of fish which could be supported in the backwater sites without supplemental feeding. The unfed net pen treatments were designed to determine growth and survival without the influence of predation which would occur in the barrier net.

This report consists of a summarization of food habits, growth, and production of unfed fish reared during 1984-1987 and an update of adult returns of fed fish reared in net pens and unfed fish reared in the barrier net during this period.

METHODS

Unfed fish were reared in net pens and in a barrier net enclosure at Rock Creek (RC), river kilometer (km) 364, in 1984, 1985, and 1986, and in net pens at Drano Lake (DL), river km 261, in 1987. In 1984, unfed fish were stocked at a density of 6 g/m^3 in the net pens and 13 g/m^3 in the barrier net. During rearing trials in 1985-1987, unfed fish were stocked in net pens at low (32 g/m^3), medium (64 g/m^3), and high densities (128 g/m^3) and in the barrier net at 20 g/m^3. The barrier net treatment was not used in 1987. In 1984 and 1985, predatory fish were not removed from within the barrier net enclosure, however, due to the high mortality rates estimated in 1985, predators were removed from the enclosure prior to fish planting in 1986.

The numbers of fish stocked and released from the net pens was determined by weighing several pounds of fish and counting the number weighed to arrive at an average number per pound estimate. Total pounds of fish stocked into each pen was then converted to numbers of fish using this estimate. Numbers stocked into the barrier net were determined using the same method. Calculation of the number released from the barrier net was made using Chapman's modification of the Petersen mark-recapture procedure.

A sub-sample of 50 fish was removed from the hatchery and each off-station treatment bi-weekly and preserved in 10 % formalin for subsequent length and weight measurements.

Instantaneous growth was calculated as $(\ln(W_{t2}) - \ln(W_{t1}) / t2 - t1) \times 10^2$, where W = weight in grams, t1 = Julian date at the beginning of rearing period and t2 = Julian date at the end of the period.

Zooplankton samples were collected weekly during the periods of fish rearing in 1984-1987. In 1984 and 1987 a Miller sampler was used, but a Wisconsin tow-net was used during other years.

Stomachs from lo-56 unfed fish reared at each density and rearing method (treatment) were examined each year. Food items were identified and enumerated. Data for each item are expressed as the mean number per stomach, the percent occurrence, and the percent of the total number of food items (TN); weights of the food items were not measured.

All treatments except the fish reared in the unfed pens in 1984-1987 and in the barrier net in 1984 were coded-wire tagged. A combination of trap nets and weirs were used to capture adults returning to the rearing sites during 1985-1989. A Merwin trap-net was the most effective means of capturing returning adults at RC. Fish reared in DL are expected to return to the fish ladder at the Little White Salmon National Fish Hatchery. Due to the lack of recaptures, efforts to collect adults at Social Security Pond have not been made since 1986. Data on contributions to the ocean and in-river fisheries are from the Pacific Marine Fish Commission database. Data are current as of January 1990. Some data are preliminary.

RESULTS

FOOD HABITS OF UNFED FISH

Foods Available

Mean numbers of zooplankton at RC and DL were typically low until mid-late May (Figure 1; Appendices 1 and 2). Zooplankton densities during the rearing periods at RC were generally highest in 1984 and lowest in 1985, although mean numbers increased dramatically late in May of 1985. Zooplankton densities at DL were much lower than those at RC, but trends were similar. A large number of chironomid larvae were observed colonizing the sides of the net pens at RC in 1985.

Foods Utilized

Fish in net pens consumed zooplankton as their primary food item but supplemented their diet with insects, primarily chironomid larvae (Figures 2, 3, and 4; Appendix 3). Zooplankton usually comprised over 92% TN. Mean numbers of food items per stomach were highest during 1984 (151.1) when the rearing density was the lowest of any year. Mean numbers of food items per stomach in 1986 were generally higher than those observed during 1985 or 1987. The highest mean numbers per stomach (172.3) occurred in the high density during 1985, due to a large number of bryozoan statoblasts (163.6). As the rearing density increased in 1985, the number of chironomid larvae in the

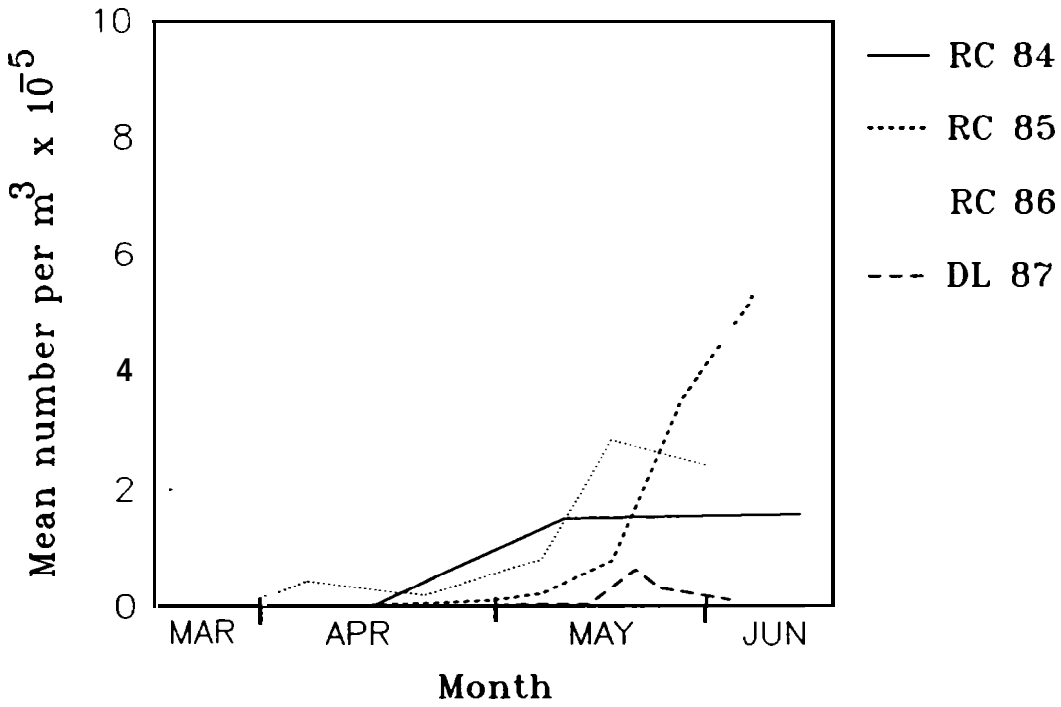


Figure 1. Mean numbers of zooplankton in Rock Creek (RC) and Drano Lake (DL), 1984-87.

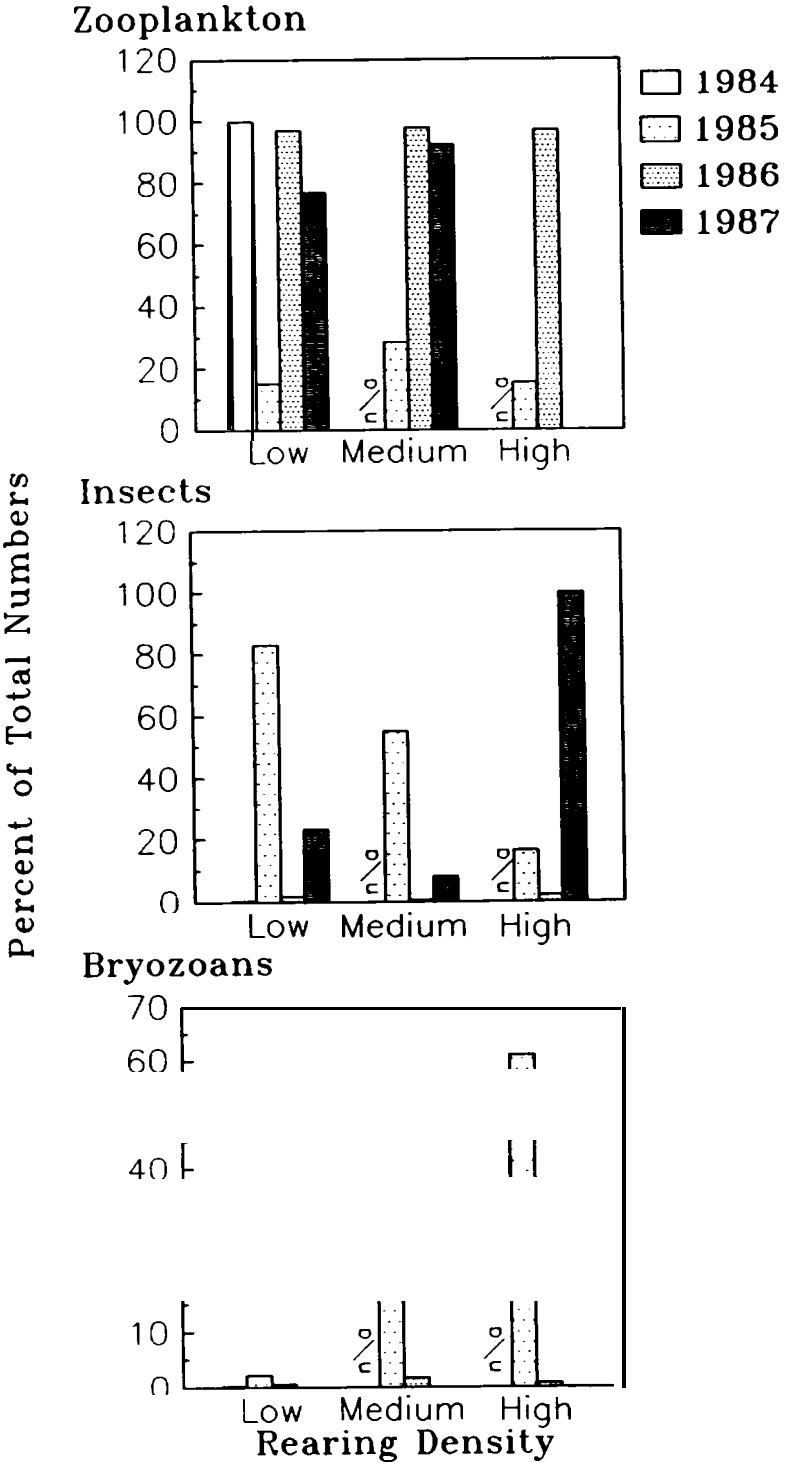


Figure 2. Percent of the total numbers of food items in stomachs of unfed fall chinook salmon reared in net pens, 1984-87.

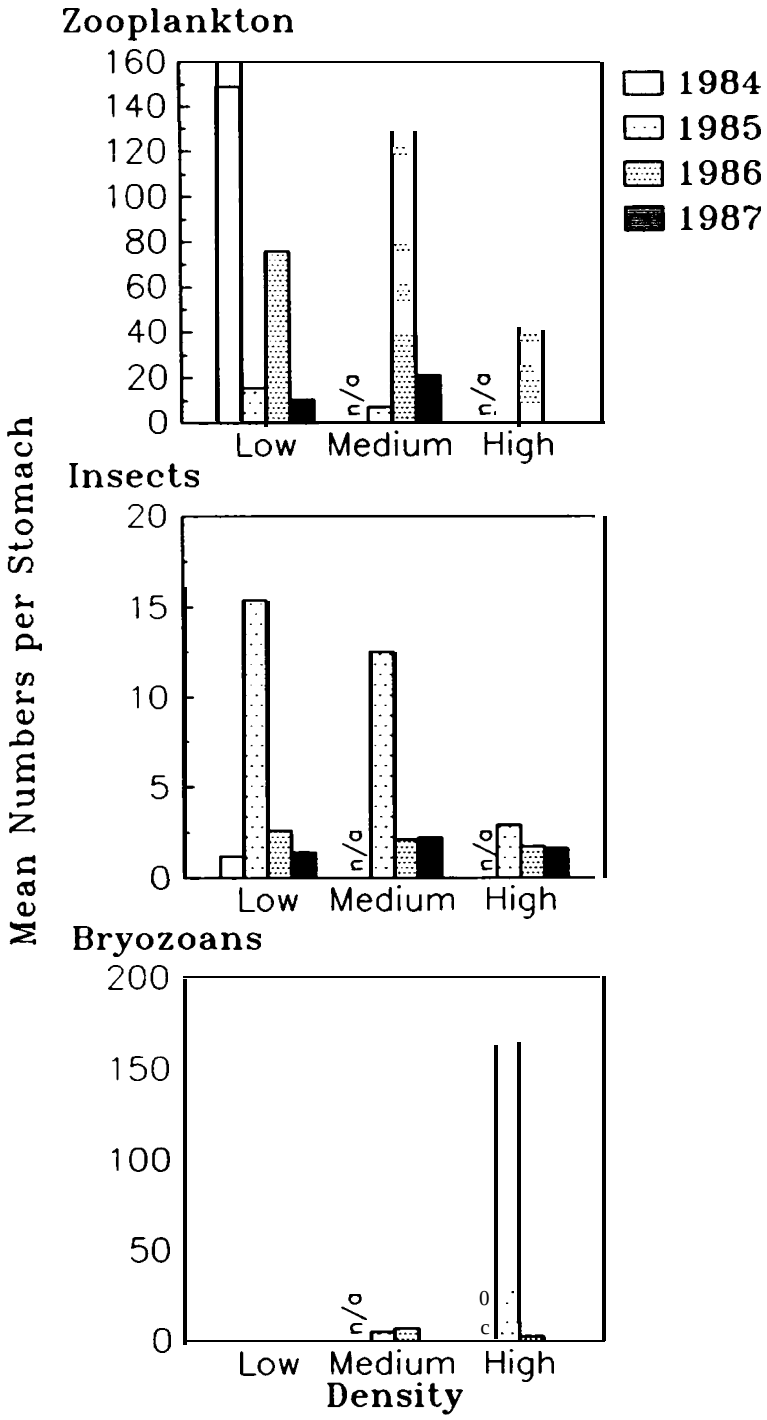


Figure 3. Mean number of food items per stomach of unfed fall chinook salmon reared in net pens, 1984-87.

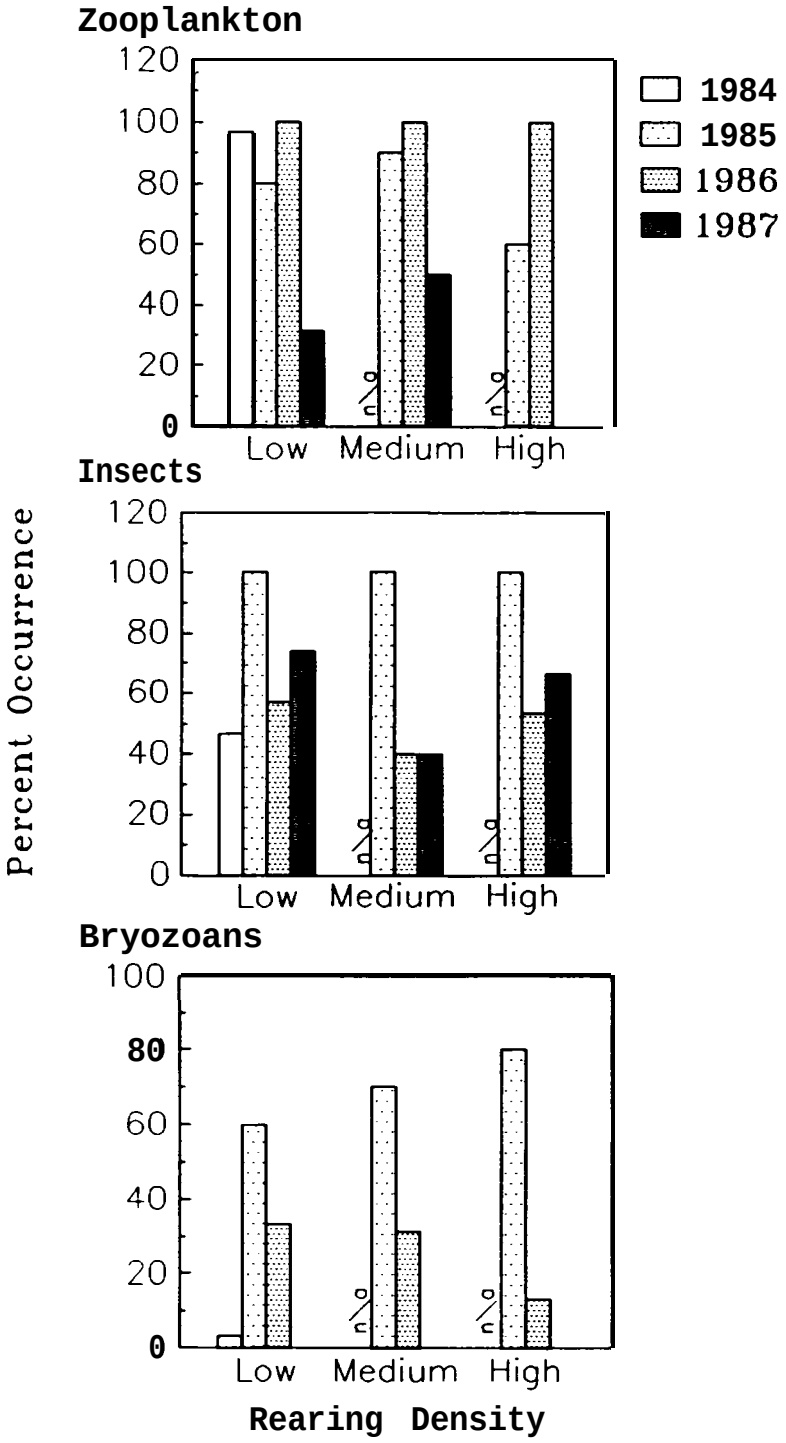


Figure 4. **Percent occurrence of food items in stomachs of unfed fall chinook salmon reared in net pens,** 1984-87.

diet decreased and the number of bryozoan statoblasts increased. Chironomid larvae comprised over 67% TN in stomachs from fish reared at the low density in 1985. The lowest mean number of food items occurred in stomachs of fish reared at the high density treatment in 1987 (1.6); no zooplankton were present in these stomachs.

Zooplankton were the primary food item of fish reared in the barrier net, making up nearly 100% TN (Figure 5; Appendix 4). The proportions of cladocerans and copepods in the stomachs were nearly equal in 1985 and 1986, but cladocerans were a more important food item in 1984, comprising 81% TN. Mean numbers of food items per stomach declined from a maximum of 290.1 in 1984 to 178.6 in 1986 and 91.4 in 1985. This trend was similar to the pattern of zooplankton abundance during these years.

GROWTH AND PRODUCTION OF UNFED FISH

Instantaneous growth rates of fish in the unfed treatments were much lower than those of the regular density fed treatment and the hatchery controls, except in 1985, when growth in the low and medium density unfed pens was better than growth of the hatchery control (Figure 6). A net loss of weight occurred in fish reared at the low density in 1984, the medium density in 1987, and at the high density in 1986 and 1987. The barrier net was the only unfed treatment where fish showed a net gain in weight each year.

Production of fish from the unfed pen and barrier net

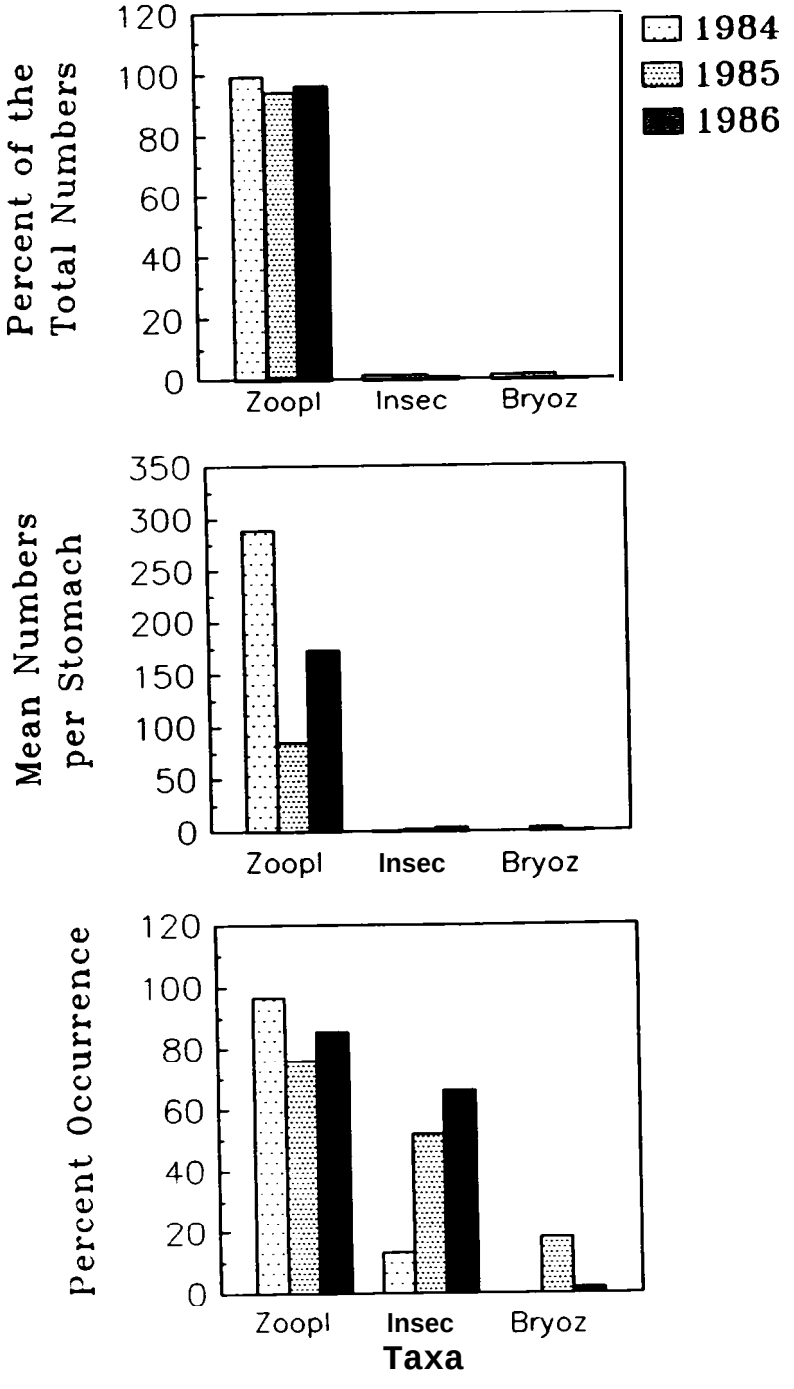


Figure 5. Percent of the total number, mean number-per stomach, and percent occurrence of food items in stomachs of unfed fall chinook salmon reared in a barrier net enclosure, 1984-86.

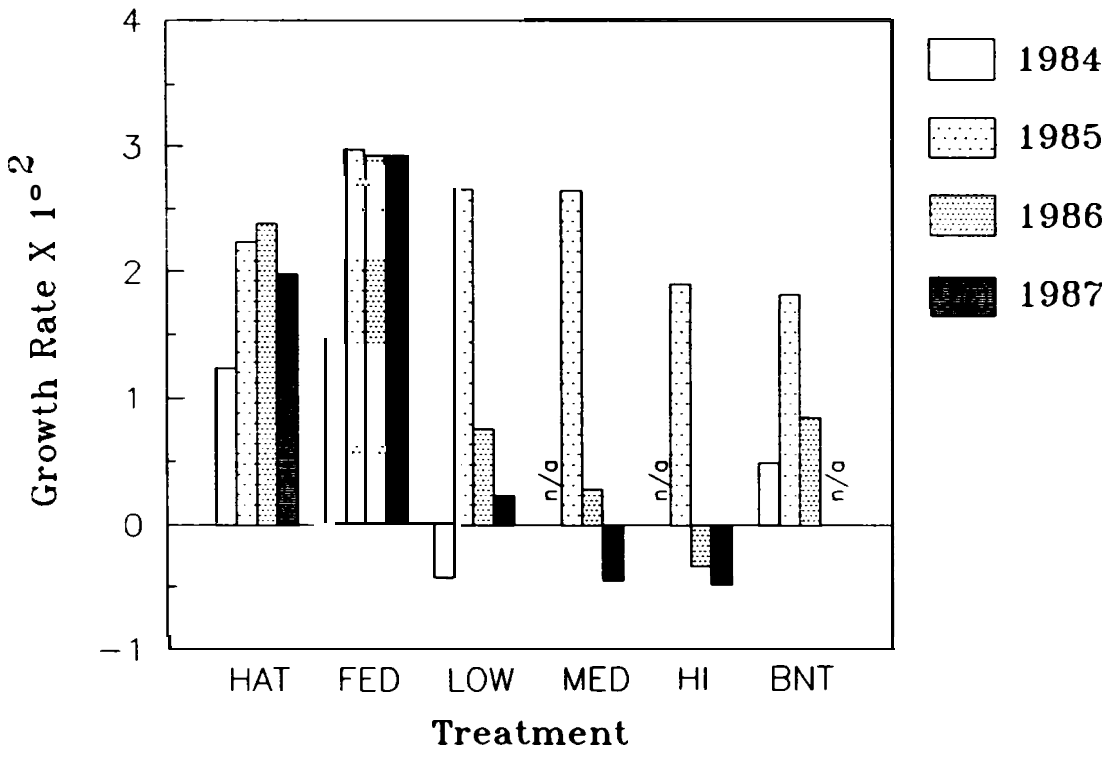


Figure 6. **Instantaneous growth rates of fall chinook salmon reared at the hatchery (HAT) and in net pens at the regular density fed treatment (FED) and without supplemental feeding at a low (LOW), medium (MED), and high (HI) density and in a barrier net enclosure (BNT), 1984-87.**

treatments was low (Table 1). The best fish production was from the unfed pens in 1984, with a net gain of 0.019 kg/m^3 over the 42 day rearing period; this treatment had the lowest rearing density during the study. With the exception of the medium density treatment in 1986, the medium and high density treatments resulted in a net loss of biomass each year.

ADULT RETURNS FROM FED TREATMENTS AND THE BARRIER NET

To facilitate comparisons between hatchery and off-station return rates, total percent returns of fish reared at RC and SSP were adjusted for an average 26% loss of out-migrants in each project encountered before arriving at the Bonneville pool, where controls were released (N=2 Sims and Ossiander 1981). While this may seem high, given that fall chinook are smaller and migrate slower than spring chinook salmon, with which the estimate was made, it is probably an underestimate of the combined effects of mortality due to dam passage and predation in Columbia River reservoirs (Rieman et al. 1988).

Adjusted adult returns from fish reared off-station are lower than those of control groups reared at LW, but are in the range of survival of releases from Columbia River hatcheries (Vreeland 1988) (Table 2). Vreeland (1988) lists survival of 1978-81 brood fall chinook reared in Columbia River hatcheries from less than 0.05% to 2.20%.

In general, recoveries of 4-year old fish have been higher

Tablel. Summary of mean number of fish stocked and released, mean mortality (percent), mean weight/fish at stocking and at release, lengths of respective rearing periods, mean density at stocking and at release, and net production among unfed fish reared in pens at low, medium, and high density and in the barrier net at Rock Creek in 1985 and 1986, and Drano Lake in 1987.

Treatment and year	Number of fish per pen\a		Mortality\b (%)	Weight (g)		Rearing period	Density\c (kg/m^3)		Net Production (kg/m^3)
	Stocking	Release		Stocking	Release	(d)	Stocking	Release	
Low									
1984	518	484	3.5	2.8	6.8	42	.018	.037	0.019
1985	1034	875	2.5	1.5	1.8	24	.020	,020	0.000
1986	968	848	1.0	2.3	3.0	60	.028	.032	0.004
1987	991	894	0.2	1.0	1.2	49	.013	,013	0.000
Medium									
1985	2036	1787	9.8	1.5	1.7	24	.039	.038	-0.001
1986	1652	1478	3.0	2.3	2.6	60	.048	.050	0.002
1987	1982	1876	0.8	1.0	0.8	49	.026	,019	-0.007
High									
1985	4249	3104	22.7	1.5	1.5	24	.081	.059	-0.022
1986	3702	3399	4.7	2.3	2.0	60	.108	.088	-0.002
1987	3964	3508	10.6	1.0	0.8	49	.051	.037	-0.014
B. Net									
1984	79442	55780	29.7	2.8	5.5	42	.018	,021	0.003
1985	254,194	129,764	49.0	1.5	2.7	48	.016	.018	0.002
1986	219,466	218,152	0.4	1.6	2.0	60	.020	,024	0.004

a/ Mean value of two replicates for fish reared in pens.

b/ Includes only natural mortality; sampling mortality accounted for an additional 100-150 fish/pen.

c/ Projected stocking densities of .032, .064, and .128 kg/m3 were based on a mean stocking size of 2.0 g per fish; actual weights of fish at stocking varied.

than recoveries of 2 or 3-year old fish. Returns from RC in 1985 and 1986, although incomplete, are much lower for the barrier net and double and triple density fed treatments (1986 only) than for the regular density treatment. Recoveries of 2 and 3-year old fish reared in DL show the triple density to have the greatest rate of return, followed by the regular density. This is largely due to a relatively large number of in-river recoveries of 3-year olds.

On-site recaptures of fish reared off-station in 1984 and 1985, the most complete data at this time, have been much lower than the ocean and in-river harvests (Table 3); no fish have been recovered at SSP. Total returns of fish reared at RC in 1984 were much higher than those from SSP, but recoveries were about equal in 1985. Adjusted returns from the barrier net treatment in 1985 were considerably lower (mean = .644%) than those of the fed fish treatments at RC (mean = 1.072%).

Numbers of adults recovered at RC in 1989 were equal in October and November (Table 4). In past years, most recoveries have occurred in November. Seven marked adults were captured, three of which were from this study.

Table 2. Adult recoveries fromreleases at Rock Creek (RC), Social Security pond (SSP), Drano Lake (DL), and the Little White salmon National Fish Hatchery (LW). Fed pen treatments listed include regular (Reg), double (Dbl), triple (Trp) and quadruple (Qua) densities. Bnt denotes the barrier net treatment. Cm-site recoveries from RC and SSP are absolute numbers, all others are expanded.

Release Year	Treat-ment	Number Tagged	Location/ Code	Cm-site Recovery					Ocean Recovery					In-river Recovery				
				2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
1984	Reg	72027	SSP/H50606	0	0	-	-	-	3	32	36	6		8	14	49	17	-
	Reg	79610	RC/H50607	10	1	0	-	-	6	125	81	5		14	60	108	14	-
	--	94847	LW/051337	26	11	51	-	-	25	97	188	49		13	53	257	100	6
1985	Reg	99169	SSP/H50702	0	-	-	-	-	9	50	147		-	3	136	288	38	-
	Reg	105406	SSP/H50703	0	-	-	-	-	17	37	99	1	-	6	107	256	21	-
	Reg	96145	RC/H50701	3	1	-	-	-	12	45	111		-	8	153	261	66	-
	Reg	99919	RC/H50704	2	2	-	1	-	8	38	87		-	0	58	243	30	-
	Bnt	60579	RC/H50705	3	2	-	-	-	0	5	35		-	0	31	83	11	-
	Bnt	63813	RC/H50706	7	3	-	-	-	1	16	32		-	0	69	120	23	-
	--	22393	LW/051250	0	3	9	12	-	2	25	21		-	0	27	58	14	-
		23100	LW/051251	0	8	20	15	-	9	111	94		-	0	26	98	46	-
		21864	LW/051256	0	3	28	13	-	7	46	72		-	3	16	137	56	-
		26499	W/051257	2	11	31	23	-	6	69	105		-	4	56	129	65	-
	--	20075	LW/051252	0	2	18	9	-	5	78	68		-	0	38	88	23	-
		21158	LW/051253	2	9	23	13	-	0	60	41		-	0	25	76	41	-
		25467	LW/051254	0	9	24	17	-	3	81	45		-	3	31	91	50	-
		25505	LW/051255	1	15	28	17	-	3	70	61		-	0	16	140	64	-

(Table 2 continued.)

Release Year	Treatment	Number Tagged	Location/ Code	On-site Recovery 2	3	4	5	6	Ocean Recovery 2	3	4	5	6	In-river Recovery 2	3	4	5	6
1986	Reg	50840	SSP/B50312	–			–	–	0	8		–	–	0	25	40	–	–
	Reg	52946	SSP/B50315	–			–	–	2	1		–	–	0	4	18	–	–
	Reg	52387	SSP/B50314	–			–	–	0	5		–	–	0	11	25	–	–
	Reg	54598	SSP/B50313	–			–	–	0	0		–	–	0	4	45	–	–
	Reg	50757	RC/B50308	0			–	–	0	6	7	–	–	0	5	14	–	–
	Reg	50817	RC/B50309	0		1	–	–	0	0		–	–	0	4	12	–	–
	Reg	51996	RC/B50310	0		–	–	–	0	5		–	–	0	10	22	–	–
	Reg	52360	RC/B50311	0		–	–	–	0	0		–	–	0	9	35	–	–
	Dbl	35427	RC/B50409	0		–	–	–	0	4		–	–	0	0	–	–	–
	Dbl	35376	RC/B50408	0		–	–	–	0	1		–	–	0	0	15	–	–
	Trp	52631	RC/B50215	0		1	–	–	0	1		–	–	0	4	16	–	–
	Trp	53208	RC/B50214	0			–	–	0	0		–	–	0	4	13	–	–
	Bnt	51851	RC/B50213	0			–	–	0	0		–	–	0	0	–	–	–
	Bnt	52128	RC/B50212	0			–	–	0	0		–	–	0	0	5	–	–
	Bnt	51851	RC/B50211	0			–	–	0	0		–	–	0	0	13	–	–
	Bnt	51850	RC/B50210	0			–	–	0	0		–	–	0	0	–	–	–
		48146	LW/051810	0	3	9	–	–	0	4		–	–	0	12	17	–	–
		48147	LW/051809	0	2	7	–	–	0	4		–	–	0	11	32	–	–
		49443	LW/051807	0	3	7	–	–	0	2		–	–	0	11	–	–	–
		49574	LW/051808	0	5	12	–	–	5	7		–	–	0	12	27	–	–
1987	Reg	47731	DL/B50101	0	2		–	–	6	3		–	–	0	31	–	–	–
	Reg	49839	DL/B50102	1	3		–	–	5			–	–	0	14	–	–	–
	Reg	49947	DL/B50103	1	2		–	–	0			–	–	0	3	–	–	–
	Reg	47400	DL/B50104	2	2		–	–	0			–	–	10	6	–	–	–
	Dbl	31671	DL/B50105	2	4		–	–	3			–	–	0	3	–	–	–
	Dbl	34209	DL/B50106	1	3		–	–	0	3		–	–	0	3	–	–	–
	Trp	49720	DL/B50713	0	2		–	–	4	–		–	–	0	17	–	–	–
	Trp	48285	DL/B50714	1	2		–	–	0	–		–	–	0	23	–	–	–
	Qua	59682	DL/B50201	0	3		–	–	0	–		–	–	0	14	–	–	–
	Qua	62157	DL/B50202	1	7		–	–	1	3		–	–	0	14	–	–	–

Table 3. Adult recovery summaries (number and percent) of fish released at Rock Creek (RC), Social Security Pond (SSP), and controls released at the Little White Salmon NFH (LW), including totals for each area of recovery (on-site, ocean, or in-river) for 1984 and 1985. Adjusted total returns account for an average of 26 % loss of out-migrants at each project (n=2) for fish released in the John Day pool, prior to entering the Bonneville pool, where controls were released. On-site recoveries from RC and SSP are absolute numbers, al.1 others are expanded.

Treat-ment	Location/ Code	Number Released	Adjusted Number	On-site		Ocean		In-river		Total		Adjusted Total Returns (%)
				No.	%	No.	%	No.	%	No.	%	
1984												
Reg	SSP/H50606	72027	39442	0	0	77	.107	88	.122	165	.229	.418
Reg	RC/H50607	79610	43594	11	.014	217	.273	196	.246	424	.533	.973
--	LW/051337	94847	--	88	.093	329	.347	429	,452	846	.892	--
1985												
Reg	SSP/H50702	99169	54305	0	0	206	,208	465	.469	671	.677	1.236
Reg	SSP/H50703	105406	57720	0	0	154	.146	390	.370	544	.517	.944
Reg	RC/H50701	96145	52649	4	.004	168	.175	488	.508	660	.686	1.253
Reg	RC/H50704	99919	54716	5	.005	133	.133	331	.331	469	.469	.856
Bnt	RC/H50705	60579	23967	5	.008	40	.066	125	.206	170	.281	.513
Bnt	RC/H50706	63813	34944	10	.016	49	.077	212	.332	271	.425	.776
--	LW/051250	22393	--	24	.107	48	.214	99	,442	171	.763	--
--	LW/051251	23100	--	43	.186	214	.926	170	.736	427	1.848	--
--	LW/051256	21864	--	44	.201	125	.572	170	.956	378	1.729	--
--	LW/051257	26499	--	67	.253	180	.679	250	.943	497	1.876	--
--	LW/051252	20075	--	29	.144	151	.752	149	,742	329	1.639	--
--	LW/051253	21158	--	47	.222	101	.477	142	.671	290	1.371	--
--	LW/051254	25467	--	50	.196	129	.506	172	.675	351	1.378	--
--	LW/051255	25505	--	61	.239	134	.525	220	.863	415	1.627	--

Table 4. Summary of weekly jack (J) and adult (A) returns to Rock Creek, fall sampling, 1985-89. Number of marks recovered are included in parentheses.

		Recovery Year									
		1985		1986		1987		1988[1,2]		1989[2]	
Date		J	A	J	A	J	A	J	A	J	A
Sept	17-23	0	0	0	0	0	0	1	0	0	0
	24-30	0	0	1	0	0	0	0	0	0	0
Oct	l-7	0	0	4	1	3	0	2	1	5	1
	8-15	0	0	4	2	1	3	0	0	1	1
	16-23	18	0	5	3	1	1	1	2	0	6
	24-31	10	0	9	6	2	2	0	1	0	3
Nov	l-7	26	0	25	13	8	4	0	0	0	1
	8-15	30	0	87	21	18	4	0	1	1	5
	16-23	11	0	52	10	13	30	0	4	0	4
	24-30	0	0	9	7	3	5	0	0	0	1
Dec	l-7	0	0	9	5	0	1	0	0	0	0
	8-15	0	0	2	0	0	2	0	0	0	0
Total		95	0	207	62	50	52	4	9	7	22
Marked		**(10)**	-	(15)	(1)	(5)	(9)	(0)	(6)	(0)	(7)

[1] Vandals and river otters took an unknown number of fish over the collection period.

[2] Fish reared in 1987 are expected to return to the fish ladder at the Little White Salmon National Fish Hatchery at the Drano Lake rearing site (included as on-site recoveries in Table 2).

DISCUSSION

The diets of unfed fish reared in the net pens and barrier net were slightly different. Zooplankton was the primary food item of fish in both treatments, but stomachs of fish reared in the net pens had more chironomid larvae than those from the barrier net. Chironomids were observed colonizing the sides of the net pens in 1985. As seen in 1985, this can be a significant food base for fish reared in net pens.

Growth of fish in the unfed treatments was generally poor and sometimes non-existent. Zooplankton densities were insufficient to allow appreciable growth in most years. However, in 1985, growth in the low and medium densities was greater than that of the hatchery controls. This was due to the combination of the sharp increase in zooplankton numbers in mid-May and the availability of chironomid larvae colonizing the sides of the pens. Large numbers of chironomid larvae were not seen colonizing the net pens in other years, and we do not know why they were so prevalent in 1985.

Production of unfed fish was low. Fish reared in net pens did poorly at the two higher densities, and only two of the four trials at the low density resulted in a net gain in production. Fish reared in the barrier net also had low production, but a net gain was achieved each year. Removing predators from within the enclosure in 1986 increased production over levels observed in 1984 and 1985.

Adult returns of fish from the fed treatments and barrier net continue to lag behind those of control fish reared in the hatchery, but are higher than those of this and other Columbia River hatcheries in some years (Vreeland 1988). Differences are most notable in the on-site recoveries, where off-station numbers are low at RC and zero at SSP.

Preliminary data indicates that there may be an inverse relationship between rearing density and return rate. A similar relationship has been observed in fish reared at the Carson NFH (personal communication, Joe Banks, USFWS, Abernathy Salmon Culture Technology Center).

Despite lower return rates for the net pen reared fish compared to those of the hatchery controls, due to the lower costs, net pen rearing may still be a viable tool, especially for for holding "thinning" releases until a more desireable size is achieved prior to release.

SUMMARY

1) Zooplankton were the primary food item of unfed fall chinook salmon reared in net pens and in a barrier net enclosure.

2) Insects colonizing net pens may provide significant contributions to the food base of unfed fish reared in net pens, but not inside large barrier net enclosures.

3) Growth of unfed fish was very poor unless zooplankton densities were high and/or other natural food bases were available.

4) Zooplankton densities in backwaters tested were not sufficient for a net gain in production of unfed fish when rearing densities were greater than 32 g/m^3.

5) Preliminary data indicates adult returns from treatments reared off-station are lower than those of control fish reared at the Little White Salmon National Fish Hatchery, but are not unlike returns from fish reared in this or other Columbia River hatcheries in some years. Rearing fall chinook salmon in net pens may be an economical method for holding hatchery "thinning" releases until a more desireable release size is reached.

ACKNOWLEDGEMENTS

We would like to thank Donna Allard, Brian Cates, Alan Ecklund, Keith Hatch , and Walt Ambrogetti of the Vancouver, WA, Fisheries Assistance Office, for operating the Merwin trap net at Rock Creek, and Keith Hatch again, for collating adult return information. We also thank Bill Nelson and Curt Burley for review of this manuscript. This project was funded by the Bonneville Power Administration, U.S. Department of Energy, Portland, OR.

LITERATURE CITED

Novotny, J.F., T.L Macy, and J.T. Gardenier. 1984. Pen rearing and imprinting of fall chinook salmon: Annual Report 1983. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 25 pp.

Novotny, J.F., T.L Macy, and J.T. Gardenier. 1985. Pen rearing and imprinting of fall chinook salmon: Annual Report 1984. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 61 pp.

Novotny, J.F., T.L Macy, and J.T. Gardenier. 1986a. Pen rearing and imprinting of fall chinook salmon: Annual Report 1985. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 65 pp.

Novotny, J.F., T.L Macy, J.T. Gardenier, and John W. Beeman. 1986b. Pen rearing and imprinting of fall chinook salmon: Annual Report 1986. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 78 pp.

Novotny, J.F., T.L Macy, M. P. Faler, and John W. Beeman. 1987. Pen rearing and imprinting of fall chinook salmon: Annual Report 1987. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 69 pp.

Novotny, J.F., and Thomas L. Macy. 1988. Pen rearing and imprinting of fall chinook salmon: Annual Report 1988. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 114 pp.

Rieman, B. E., Beamesderfer, R.C., Vigg, S., and Thomas P.Poe. 1988. Predation by resident fish on juvenile salmonids in a mainstem Columbia reservoir: Part IV. Estimated total loss and mortality of juvenile salmonids to Northern Squawfish, Walleye, and Smallmouth Bass. In Predation by resident fish on juvenile salmonids in John Day Reservoir: Volume I-Final Report of Research. Thomas P.Poe Ed. Prepared by U.S. Fish and Wildlife Service for Bonneville Power Administration, Portland, OR. 377 pp.

Sims, C.W., and S.J. Ossiander. 1981. Migrations of fall chinook salmon and steelhead trout in the Snake River from 1973 to 1979. Report to U.S. Army Corps of Engineers, Portland, OR. 43 pp.

Vreeland, R.R. 1988. Evaluation of the contribution of chinook salmon reared at Columbia River hatcheries to the pacific salmon fisheries. Annual Report FY 1987. Prepared by National Marine Fisheries Service for Bonneville Power Administration, Portland, OR. 113 pp.

Appendix l. Number of zooplankton per m^3 collected at Rock Creek, 1984-86. Samples were collected with a Miller sampler in 1984 and with a Wisconsin net in 1985-86. T = trace (Cl).

1984

TAXON	DATE 4/20	5/14	6/16
Copepoda			
Cyclops spp.	2620	54625	29323
Diaptomus spp.	0	104	440
Clad-			
Bosmina spp.	898	86458	7702
Ceriodaphnia spp.	0	0	0
Chydorus spp.	66	0	0
Daphnia spp.	386	8430	118109
Diaphanosoma spp.	0	104	0
Leptodora spp.	0	0	286
other	0	0	0
Totals	3970	149721	155860

1985

TAXON	DATE 4/11	4/26	5/02	5/09	5/21	5/30	6/05	6/10
Copepoda								
Cyclops spp.	300	6300	10000	22400	47400	55100	111300	87400
Diaptomus spp.	0	0	300	0	0	0	0	1600
Clad-								
Bosmina spp.	300	0	0	0	18100	291700	396000	**695400**
Ceriodaphnia spp.	0	0	0	0	0	0	0	**0**
Chydorus spp.	0	0	0	0	2300	0	0	**0**
Daphnia spp.	0	**300**	0	**700**	0	**2000**	**11000**	**111500**
Diaphanosoma spp	0	**0**	0	0	0	**0**	**0**	**0**
Leptodora spp.	0	0	0	0	0	0	0	0
other	0	0	0	0	0	**2000**	**1000**	**3200**
Totals	**600**	6600	10300	23100	67800	350800	519300	899100

(Appendix 1 continued)

1986

DATE

TAXON	3/04	3/25	4/10	4/25		5/21	6/03
Copepoda							
Cyclops spp.	T	T	39900	16100	70400	97200	24800
Diaptomus spp.	0	0	T	T	T	0	T
Clad-							
Bosmina spp.	0	T	600	1200	7200	178900	176400
Ceriodaphnia spp.	0	0	0	0	T	600	15300
Chydorus spp.	800	T	600	600	0	3100	800
Daphnia spp.	0	0	600	T	1800	3000	26000
Diaphanosoma spp	0	0	0	0	0	0	T
Leptodora spp.	0	0	0	0	0	0	0
other	600	T	0	0	0	T	0
Totals	1400	T	41700	17900	79400	282800	239900

Appendix 2. Number of zooplankton per m^3 collected at Drano Lake in 1987. Samples were collect with a Miller sampler. T = trace (<1).

	DATE											
TAXON	3/04	3/18	3/30	4/09	4/16	4/21	4/29	5/07	5/15	5/22	5/29	6/04
Copepoda												
Cyclops spp.	0	0	8	0	7	14	14	14	62	T	486	313
Diaptomus spp.	0	0	0	0	14	34	0	7	14	139	T	0
Cladocera												
Bosmina spp.	14	14	0	41	117	179	550	2468	3486	60160	30860	10010
Ceriodaphnia spp.	0	0	0	0	0	0	0	0	0	0	0	0
Chydorus spp.	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia spp.	0	0	0	0	0	0	0	7	14	278	T	0
Diaphanosoma spp	0	0	0	0	0	0	0	0	0	0	0	0
Leptodora spp.	0	0	0	0	0	0	0	0	0	70	0	0
other	0	0	0	0	0	0	0	0	—	—	—	—
Totals	14	14	0	41	138	227	564	2496	3576	64400	35720	13140

Appendix 3. Mean number, percent occurrence, and percent of the total number of food items in stomachs of juvenile fall chinook salmon reared without supplemental feeding in net pens at Rock Creek in 1984-86, and at Drano Lake during 1987. Sample sizes are in parentheses. T = trace (<0.1).

Year	Treatment	Food item	Mean number	Percent occurrence	Percent number
1984	Unfed [a] (30)	Zooplankton	148.9	96.7	99.6
		Cladocera	124.2	96.7	83.1
		Copepoda	25.5	93.3	16.5
		Other [b]	--	--	--
		Insects	1.2	46.7	0.4
		Chironomidae	1.2	13.3	0.1
		Other [c]	0.9	43.3	0.3
		Bryozoans	1.0	3.3	T
		Other [d]	--	--	--
1985	Low Density (10)	Zooplankton	15.4	80.0	14.9
		Cladocera	11.0	60.0	8.0
		Copepoda	8.1	70.0	6.9
		Other [b]	--	--	--
		Insects	68.7	100.0	82.9
		Chironomidae	67.8	100.0	81.8
		Other [c]	3.0	30.0	1.1
		Bryozoans	3.0	60.0	2.2
		Other [d]	--	--	--
1985	Med Density (10)	Zooplankton	7.1	90.0	28.2
		Cladocera	5.4	80.0	18.9
		Copepoda	3.0	70.0	9.3
		Other [b]	--	--	--
		Insects	12.5	100.0	55.1
		Chironomidae	14.2	80.0	50.3
		Other [c]	2.2	50.0	4.8
		Bryozoans	5.4	70.0	16.7
		Other [d]	--	--	--

(Appendix 3 continued)

Year	Treatment	Food item	Mean number	Percent occurrence	Percent number
1985	Hi Density (10)	Zooplankton	4.5	60.0	15.2
		Cladocera	1.3	60.0	4.5
		Copepoda	3.8	50.0	10.7
		Other [b]	--	--	--
		Insects	2.9	100.0	16.3
		Chironomidae	3.2	80.0	14.6
		Other [c]	0.5	60.0	1.7
		Bryozoans	163.6	80.0	61.2
		Other [d]	1.3	100.0	7.3
1986	Low Density (30)	Zooplankton	75.8	100.0	96.7
		Cladocera	43.3	73.3	45.2
		Copepoda	43.2	93.3	51.5
		Other [b]	--	--	--
		Insects	2.6	56.7	1.9
		Chironomidae	3.0	33.3	1.3
		Other [c]	1.2	40.0	0.6
		Bryozoans	1.4	33.3	0.6
		Other [d]	1.3	50.0	0.8
1986	Med Density (35)	Zooplankton	128.7	100.0	97.5
		Cladocera	106.7	97.1	78.6
		Copepoda	25.0	100.0	19.0
		Other [b]	T	91.4	T
		Insects	2.1	40.0	0.6
		Chironomidae	2.7	8.6	0.2
		Other [c]	1.8	34.3	0.5
		Bryozoans	7.0	31.4	1.7
		Other [d]	0.5	28.6	0.1
1986	Hi Density (30)	Zooplankton	42.1	100.0	96.8
		Cladocera	27.4	96.7	60.9
		Copepoda	17.4	90.0	35.9
		Other [b]	--	--	--
		Insects	1.7	53.3	2.1
		Chironomidae	2.4	33.3	1.9
		Other [c]	0.3	30.0	0.2
		Bryozoans	2.8	13.3	0.8
		Other [d]	0.7	20.0	0.3

(Appendix 3 continued)

Year	Treatment	Food item	Mean number	Percent occurrence	Percent number
1987	Low Density (19)	Zooplankton	10.5	31.6	76.8
		Cladocera	10.3	31.6	75.6
		Copepoda	1.0	5.3	1.2
		Other [b]	--	--	--
		Insects	1.4	73.7	23.2
		Chironomidae	1.9	36.8	15.9
		Other [c]	0.8	42.1	7.3
		Bryozoans	--	--	--
		Other [d]	T	5.3	T
1987	Med Density (10)	Zooplankton	20.8	50.0	92.0
		Cladocera	7.2	40.0	25.9
		Copepoda	18.5	40.0	66.1
		Other [b]	--	--	--
		Insects	2.2	40.0	8.0
		Chironomidae	2.5	20.0	4.5
		Other [c]	2.0	20.0	3.5
		Bryozoans	--	--	--
		Other [d]	T	30.0	T
1987	Hi Density (18)	Zooplankton	--	--	--
		Cladocera	--	--	--
		Copepoda	--	--	--
		Other [b]	--	--	--
		Insects	1.6	66.6	100.0
		Chironomidae	2.7	16.7	42.1
		Other [c]	1.2	50.0	57.9
		Bryozoans	--	--	--
		Other [d]	T	27.8	T

[a] Rearing density in 1984 was lower than low density of other years.

[b] Includes Alona sp., Ceriodaphnia sp., Chydorus sp., Diaphanosoma sp., Leptodora sp., and unidentifiable parts.

[c] Includes Isoptera, Thysanoptera, Coloeptera, and unidentifiable parts.

[d] Includes rocks and detritus.

Appendix 4. Mean number, percent occurrence, and percent of the total number of food items in stomachs of juvenile fall chinook salmon reared without supplemental feeding in a barrier net at Rock Creek in 1984-86. Sample sizes are in parentheses. T = trace (<0.1).

Year	Treatment	Food item	Mean number	Percent occurrence	Percent number
1984	Barrier Net (30)	Zooplankton	289.3	96.7	99.9
		Cladocera	234.0	96.7	80.8
		Copepoda	52.1	93.3	17.4
		Other [a]	29.0	16.7	1.7
		Insects	0.8	13.3	0.1
		Chironomidae	1.0	3.3	T
		Other [b]	0.7	10.0	T
		Bryozoans	--	--	--
		Other [c]	T	90.0	T
1985	Barrier Net (50)	Zooplankton	85.5	76.0	97.0
		Cladocera	44.4	64.0	42.5
		Copepoda	58.8	62.0	54.5
		Other [a]	0.6	16.0	0.1
		Insects	2.2	52.0	1.7
		Chironomidae	1.6	20.0	0.5
		Other [b]	1.9	42.0	1.2
		Bryozoans	3.3	18.0	0.9
		Other [c]	0.4	66.0	0.4
1986	Barrier Net (56)	Zooplankton	173.4	85.7	97.9
		Cladocera	108.3	67.9	48.4
		Copepoda	120.2	62.5	49.5
		Other [a]	T	30.4	T
		Insects	4.0	66.1	1.8
		Chironomidae	2.3	26.8	0.4
		Other [b]	3.4	60.7	1.4
		Bryozoans	T	1.8	T
		Other [c]	1.2	44.6	0.3

[a] Includes *Alona* sp., *Ceriodaphnia* sp., *Chydorus* sp., *Diaphanosoma* sp., *Leptodora* sp., and unidentifiable parts.
[b] Includes Isoptera, Thysanoptera, Coleoptera, and unidentifiable parts.
[c] Includes rocks and detritus.